LAPLACIAN ELECTRODE TO RECORD SMALL BOWEL MYOELECTRICAL ACTIVITY FROM ABDOMINAL SURFACE

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Abstract- **The aim of this study is to develop a system to record small intestine myoelectric activity (electroenterogram) from abdominal surface. The difficult anatomic access is a technical problem for monitoring intestinal activity, therefore most methods are invasive. It results in many problems like the low amplitude of the signal recorded and physiological interferences captured. In order to avoid these troubles, and to estimate the location of the small intestine point whose activity is being recorded, it has been implemented a tripolar concentric ring electrode in bipolar configuration (TCB). This electrode is based on laplacian theory. It was analysed the signals recorded by TCB electrode and contrasted to the internal myoelectric signal and to the signals obtained from the body surface by using two unipolar electrodes. It was carried out a surgical intervention in a Beagle dog to suture a bipolar electrode at the bowel serosa. The signals recorded were acquired and preprocessed to carry out a density power spectral analysis (periodogram). The electroenterogram captured by TCB electrode were free of ECG interferences. Its periodogram revealed a peak near 0.25 Hz, corresponding to the slow wave frequency (13 to 18 cpm) , while it rejected a peak at 0.4 Hz due to breath interference . These results show the utility of TCB electrode in order to remove interferences in abdominal surface electroenterogram acquisitions.**

***Keywords* - Electroenterogram, laplacian, electrode,bowel.**

I. INTRODUCTION

The difficult anatomic access is a technical problem for monitoring intestinal activity. Therefore most methods to study bowel motility are invasive. The most common are based on mechanical and myoelectric recordings [1].

The goal of the myoelectric techniques is to record the electroenterogram; i.e. , the bioelectric activity of the small intestine smooth muscle. The electroenterogram is composed of two signals (Fig. 1).The first one is the slow wave (SW) which is a periodical electric potential, which is omnipresent and regulates the rhythm of the intestinal muscle layer contractions. It is not an activation potential but slow and waved changes from the membrane potential [1].

Second signal is the spike burst (SB). It is fast, single or multiple changes of the electric potential. The spikes are not omnipresent as SW is. They appear on the SW plateau and causes a muscle layer mechanical contraction (Fig. 1). Therefore, SW establishes the maximum contraction frequency, while SBs are related to the instant in which a contraction appears [1, 2, 3].

The present study was supported in part by a grant (GV99-170-1-12) from the *Generalitat Valenciana* (Spain), and by a grant from the *Fondo de Investigaciones Sanitarias del Instituto Carlos III* (FIS-00/1039)(Spain).

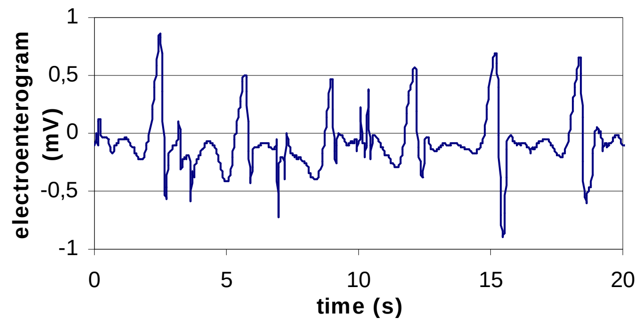

Fig. 1. Small intestine myoelectric activity (electroenterogram) recorded at duodenum level. There are approcimately 6 SW in this 20 seconds.

The correlation between SB and small intestine contractions was first found by Bass [4]. Since then, several authors have demonstrated this fact [2, 3]. There have been few attempts to record myoelectric activity from the body surface [5] in order to acquire bowel electric activity by means of a non-invasive method.

The most important problems about electroenterogram recording from the abdominal surface are the physiological interferences mixed with the studied signal, and the fact that the small bowel internal point being recorded is unknown [5]. Laplacian theory can be a solution for these problems.

Hjorth was who first recorded laplacian bioelectric potentials on the body surface, by using a five points approximation method [6]. It was not until early 90's when laplacian records on the body surface recovered researchers interest applying them to cardiology [7, 8].

Considering a local Cartesian coordinate system (x,y,z), with origin on the body surface where z axis is orthogonal to this surface, the Laplace equation can be expressed as follows:

$$Ls = \frac{\partial^2 V}{\partial x} + \frac{\partial^2 V}{\partial y} = -\frac{\partial^2 V}{\partial z} \tag{1}$$

$$Ls = -\left(\frac{1}{\sigma}\right)\cdot\left(\frac{\partial J_x}{\partial x} + \frac{\partial J_y}{\partial y}\right) \tag{2}$$

$$Ls = \left(\frac{1}{\sigma}\right)\cdot\left(\frac{\partial Jz}{\partial z}\right) \tag{3}$$

$$Ls = -\frac{\rho_{eq}}{\varepsilon} \tag{4}$$

where: Ls is laplacian on the body surface; V is the bioelectric potential; J_x, J_y are tangential components of the current density at the body surface; J_z is the normal

Report Documentation Page

Report Date	Report Type	Dates Covered (from... to)
25 Oct 2001	N/A	-

Title and Subtitle Laplacian Electrode to Record Small Bowel Myoelectrical Activity From Abdominal Surface	**Contract Number**
	Grant Number
	Program Element Number
Author(s)	**Project Number**
	Task Number
	Work Unit Number
Performing Organization Name(s) and Address(es) Grupo de Bioelectronica Departamento de Ingenieria Electronica Universidad Politecnica de Valencia. Spain	**Performing Organization Report Number**
Sponsoring/Monitoring Agency Name(s) and Address(es) US Army Research, Development & Standardization Group (UK) PSC 802 Box 15 FPO AE 09499-1500	**Sponsor/Monitor's Acronym(s)**
	Sponsor/Monitor's Report Number(s)

Distribution/Availability Statement
Approved for public release, distribution unlimited

Supplementary Notes
Papers from 23rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society, October 25-28, 2001, held in Istanbul, Turkey. See also ADM001351 for entire conference on cd-rom. , The original document contains color images.

Abstract

Subject Terms

Report Classification unclassified	**Classification of this page** unclassified
Classification of Abstract unclassified	**Limitation of Abstract** UU

Number of Pages
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component of the current density at the body surface; ρ_{eq} is the equivalent charge density.

Body surface laplacian of the bioelectric signals is negatively proportional to the two-dimensional divergence of the tangential components of the current density at the body surface, and it is proportional to the normal derivative of the current density at the body surface. The surface laplacian is also negatively proportional to an equivalent charge density, which would fully account for the actual potential distribution if the body surface were planar [7].

Therefore, laplacian records obtained from abdominal body surface are free of the ECG interference. Besides, the laplacian owns an intrinsic capability to reduce the smoothing effect presented on the records. It is due to the fact that bioelectric potential captured from the body surface is proportional to the inverse second power of the distance from the current dipole to the observation point while laplacian is inversely proportional to the fourth power of the distance from a dipole to the observation point [8]. Therefore sources closest to the measurement point are more heavily weighted, providing an enhanced resolution.

The goal of the present study is to develop a system to record electroenterogram from the abdominal body surface, based on laplacian theory. It locates more accurately the internal point captured and rejects interferences.

II. Material and Methods

In order to analyze the correlation between the myoelectric internal signals and the signals recorded from t abdominal surface, a surgical intervention was carried out in a Beagle dog for implanting a bipolar Ag-AgCl electrode sutured to the bowel serosa at the jejunum (70 cm distal to the Treitz angle). This electrode was fixed to the internal abdominal wall to locate the point which was being recorded. Recording sessions were carried out with animals in fast and with artificial respiration, started a week after surgery. Sessions lasted at least 80 minutes. In each session the TCB electrode was put on the dog abdomen, over the internal sutured electrode. The electrode had to be fastened to the body surface in order to assure good contact between the skin and the electrode. Besides, two unipolar electrodes were placed near that surface point.

The signal captured by the TCB electrode could be contrasted to the myoelectric signals captured by the internal and surface electrodes, due to the fact that the three signals were recorded simultaneously.

During the recording sessions the breath of the dog was established in 24 cycles per minute (0.4 Hz) so as to separate the electric activity due to SW from respiration interference. In these sessions, the dog was placed face down in order to assure good contact.

With the same criteria used in the design of the body surface electrodes to record laplacian electrocardiogram [9], and fitting all these parameters to the electroenterogram and to the small bowel physiology, it was designed the TCB electrode shown in Fig. 2. Tripolar electrodes can record 3

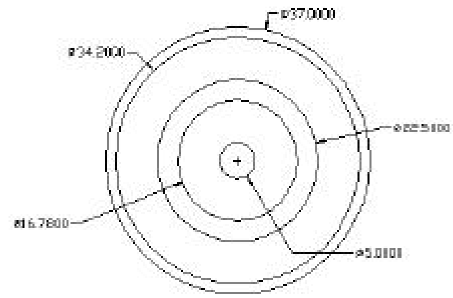

Fig. 2. Dimensions of the TCB electrode designed. Units expressed in millimeters.

signals: Vc, center dot voltage; Vm, middle ring voltage and Vo, outer ring voltage. Connecting the outer ring to the inner dot we build a TCB electrode, which let us obtain the second spatial derivative of the potential.

The signal recorded by the shorted inner dot and the outer ring was connected to the non-inverted input of a universal bioelectronic amplifier, while the signal captured by the middle ring is connected to the inverted input, giving an approximation to the second spatial derivative. Thus,

$$V_{out} = \frac{Vo + Vc}{2} - Vm = \frac{\left(\left(Vo - Vm\right) - \left(Vm - Vc\right)\right)}{2} \qquad (5)$$

$$V_{out} = \frac{\Delta Vom - \Delta Vmc}{2} \approx \frac{d^2V}{dz^2} \qquad (6)$$

where, V_{out} is the output potential of the amplifier (if gain would be 1).

The amplifier gain was set in 5000 and the low cut-off frequency was set in 0.05 Hz to remove DC component generated from the half-cell potentials between the skin and the conductor of the electrode. The high cut-off frequency was set in 35 Hz. Signals were acquired simultaneously with a sample rate of 100 Hz. An own software based on Labview® (National Instruments®) was developed to program the computer graphically for data acquisition, signal preprocessing and representation.

The acquired signals were preprocessed (scaled, filtered and decimated). The low cut-off frequency was set in 0.1 Hz to assure that DC component was removed [5]. The high cut-off frequency was set in 5 Hz in order to analyze myoelectric activity related to the intestinal slow wave, whose frequency is estimated in 13 to 18 cycles per minute. Finally a 20 per cent decimate factor was carry out; i.e., each of the three signals were 20 Hz sample rate.

The spectral analysis chosen was based on the FFT method. Unmodified periodogram was calculated with 60 seconds of window length (rectangular window). It was processed 1200 samples (60 seconds with a sample rate of 20 Hz). Zero padding was applied and 2046 samples were considered in order to improve the frequency definition. However, spectral resolution was fixed by the window length:

$$\Delta f = 1/T = 1/60s = 0.017Hz \qquad (7)$$

Periodograms were obtained as average of every minute captured in a recording session. Periodograms were calculated with the same technique for the three signals studied .

III. Results

Fig. 3 shows 20 seconds of the recorded signals. In upper trace, abdominal surface myoelectric activity recorded by means of unipolar electrodes presents electrocardiogram interference. Meanwhile, in middle trace, electroenterogram recorded by means of TCB electrode does not present this characteristic interference. This fact appears in every minute acquired.

Before analyzing the periodograms, cyclic SW can be detected in electroenterogram captured from TCB electrode. However, this repetition is not constant in every minute. Therefore periodograms must be estimated.

Fig. 4 and Fig. 5 show the periodograms calculated for the three myoelectric signals (internal, external from unipolar electrodes, and external from TCB electrode), from two different sessions (A and B). The other recording sessions presented the same results. Laplacian periodogram reveals a peak near 0.25 Hz which corresponds to SW myoelectric activity (13 to 18 cycles per minute).

It could be noticed that laplacian records present improvements by contrast to unipolar electrodes located on the body surface. While periodogram obtained from unipolar electrodes has a peak at 0.4 Hz which corresponds to respiratory frequency, laplacian periodogram has not got it (see Fig. 5). Fig. 3 and Fig. 5 ensure that TCB electrode is able to capture myoelectric activity generated by the intestine SW on the body surface rejecting physiological interferences (breath and ECG).

In Fig. 4 periodograms are slightly different from periodograms shown in Fig. 5. It is due to SW deformations. These deformations were caused in every session (like session A) where the dog was stressed, joint to tranquilizer injection.

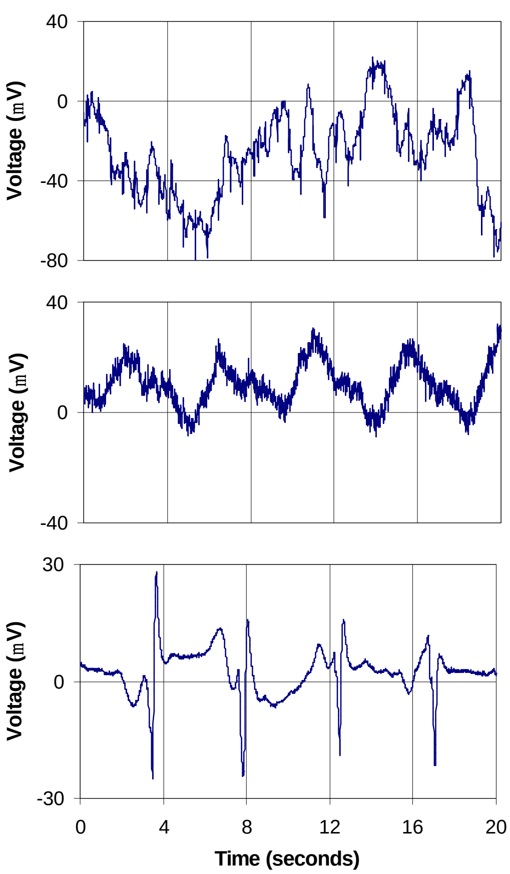

Fig. 3. Internal myoelectric signal (lower trace) and its corresponding surface signal recorded by unipolar electrodes (upper trace) and the laplacian TCB electrode (middle trace).

IV. Discussion.

Nowadays, the most techniques to acquire myoelectric activity from small bowel are invasive [1]. The aim of this study is to develop a system for recording electroenterogram from the body surface. It leads to problems like the small amplitude of the signal recorded and the interferences captured. The most critical interferences have a physiological origin: the electrocardiogram and the respiration.

TCB electrode seems to remove respiratory artifact (Fig. 5) which has a special interest in order to analyze the myoelectric signals originated by the intestine small wave because of their similar spectral frequency [5].

There are several techniques to obtain the laplacian of a bioelectric potential on the body surface. These techniques are based on calculus algorithms of discrete laplacian. The

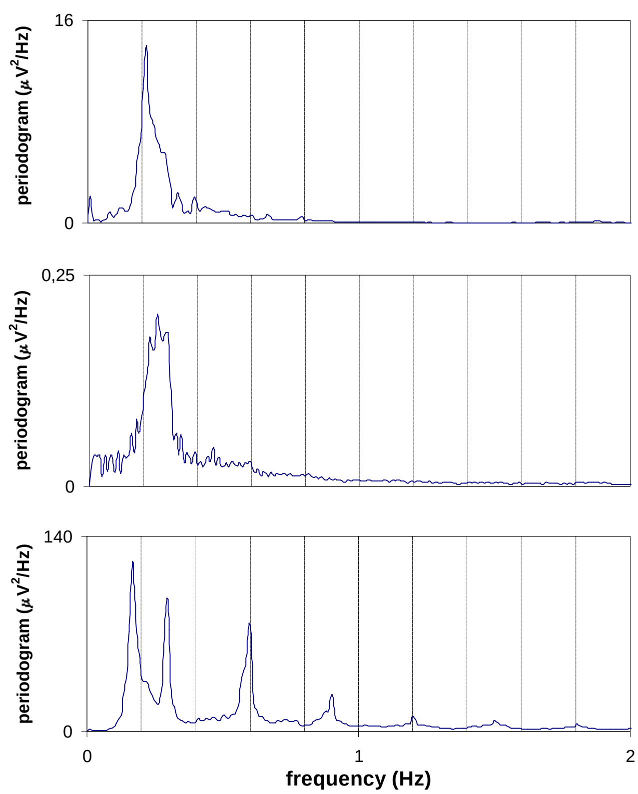

Fig. 4. Periodograms calculated in session A from pre-processed signals recorded from internal electrode (lower trace) and abdominal surface from unipolar electrodes (upper trace) and laplacian TCB electrode (middle trace).

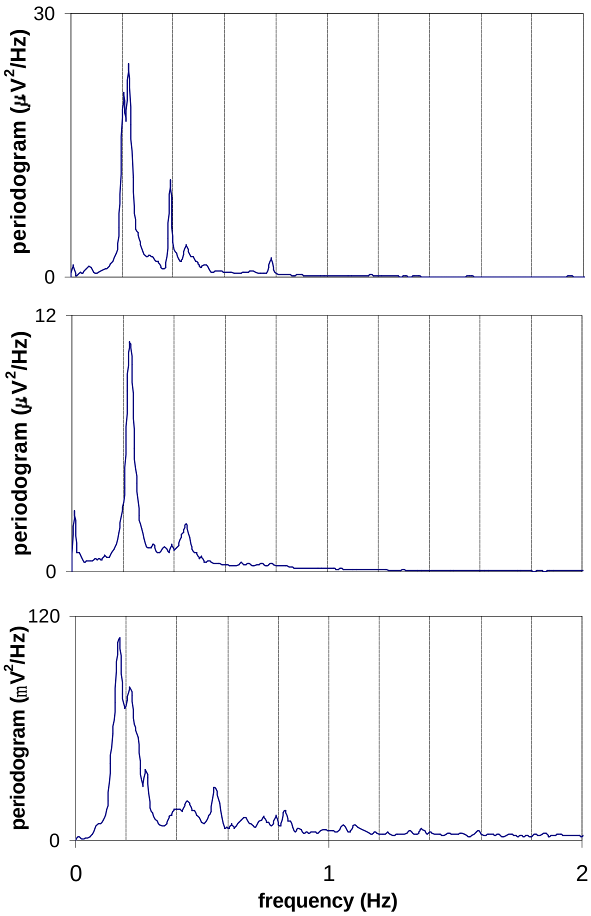

Fig. 5. Periodograms calculated in session B from pre-processed signals recorded from internal electrode (lower trace) and abdominal surface from unipolar electrodes (upper trace) and laplacian TCB electrode (middle trace).

most outstanding techniques are: the five points algorithm [6], local circular laplacian estimation and spline laplacian estimation [7, 8].

In order to obtain myoelectric laplacian, it was developed a TCB electrode. It was chosen this kind of electrode because it has a higher common mode rejection ratio than unipolar or bipolar electrodes. Furthermore, it reduces the averaging errors, simplify he recording system and allow us to obtain detailed high frequency information [9].

In Fig. 3, can be observed that records obtained on the body surface by means of unipolar electrodes present ECG interference, while laplacian records do not have this interference. This could be unimportant if the objective were to record SW of the electroenterogram, which is supported by other authors [5]. However in previous studies the present research unit has correlated the energy of the SB from the abdominal surface record with intestinal motility. Therefore, the importance of this achievement is that SB may be detected without filtering ECG.

However, at the present, periodogram analysis (see Fig. 4 and Fig. 5) of the laplacian signal reveal a peak near 0.25 Hz corresponding to the slow wave myolectric ativity (13 to 18 cycles per minute).

V. Conclusion.

It is presented a method for recording the electroenterogram from external body surface based on laplacian theory. Thanks to the TCB electrode developed, biosignals interferences could be rejected which will permit to analyze electroenterogram in order to calculate intestinal motility indexes.

Acknowledgment

The preoperative, surgical and postoperative interventions, as well as the recording sessions, were carried out in the Veterinarian Unit of the Research Centre of the "La Fe" University Hospital in Valencia (Spain), assisted by C. Vila, PhD.

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